

SEISMIC RESPONSE OF A TYPICAL 3-LEGGED JACKET OF FIXED OFFSHORE
PLATFORM IN MALAYSIA DUE TO ACEH EARTHQUAKE

NURUL NABILA BT FAZILAN

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Faculty of civil Engineering and Earth Resources
UNIVERSITI MALAYSIA PAHANG

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ABSTRACT

A level of concern among engineers in Malaysia about the crucial aspect to consider the seismic response due to earthquake in structure design still low. Majority of buildings in Malaysia is been designing based on BS8110 .However, these standards do not have any requirements on seismic loads. Actually , Malaysia have experienced the earthquake tremors due to the neighboring countries , such as Indonesia which have experienced of seismological activities in the past few year. Thus, chance of Malaysia being jolted by at least one moderate earthquake cannot be ruled out. The purposes of this study is to estimate the earthquake ground motion due to earthquake in Aceh Indonesia for assessment of offshore platform in Malaysia. Besides , by doing this study ,we could determine the vulnerability of existing offshore platform in Malaysia when subjected to loading from earthquake. The response of the fixed steel jacket offshore platform under earthquake loading (shear , displacement and bending moment) can be also determined. The region for interested offshore platform site is in Terengganu. All the environmental loads in Terengganu is given such as wave height, current velocity and wind speed are given. The ground motion acceleration from Aceh earthquake also be given. There are three type of seismic response analysis in this study which are free vibration analysis , time history analysis and response spectrum analysis. In free vibration analysis, 12 mode shape is analyses. For the response spectrum analysis ,the analysis is based on response spectra of EuroCode 8.While for the time history analysis ,is referring to the time history of Aceh's earthquake in 2004. SAP2000 computer software is chosen to analyses the earthquake response to the steel jacket offshore platform. The steel structure is design according to EuroCode 3 standards.

ABSTRAK

Tahap keprihatinan dalam kalangan jurutera di Malaysia mengenai kepentingan mempertimbangkan respons seismik oleh gempa bumi dalam struktur reka bentuk adalah masih rendah. Majoriti bangunan di Malaysia direka bentuk berdasarkan standard BS8110. Walaubagaimanapun, standard ini tiada keperluan dimana tiada beban seismik. Sebenarnya, Malaysia pernah merasai gegaran gempa bumi disebabkan negara jiran seperti Indonesia yang mengalami aktiviti seismik sejak beberapa tahun ini. Oleh itu, keberangkalian Malaysia untuk mengalami sekurang-kurangnya gempa bumi sederhana tidak boleh diremehkan. Tujuan kajian ini adalah untuk menganggarkan gerakan gempa bumi berpunca dari gempa bumi Aceh, Indonesia untuk penilaian platform luar pesisir di Malaysia. Selain itu, dengan menjalankan kajian ini, dapat menentukan kelemahan platform luar pesisir yang sedia ada di Malaysia apabila dikenakan beban gempa bumi. Respons platform luar pesisir jaket keluli tetap oleh beban gempa bumi seperti ricih, anjakan dan momen lentur dapat ditentukan. Kawasan kajian untuk platform di luar pesisir pantai adalah di Terengganu. Semua beban persekitaran di Terengganu seperti ketinggian ombak, halaju arus dan kelajuan angin adalah diberikan. Pecutan pergerakan bumi dari Aceh, Indonesia juga diberikan. Tiga jenis analisis dijalankan dalam kajian ini iaitu analisis getaran bebas, analisis sejarah masa dan tindak balas analisis spektrum. Dalam analisis getaran bebas, 12 bentuk mod dianalisis. Bagi tindak balas analisis spektrum, analisis berdasarkan dari respons spektra oleh Kod Euro 8. Manakala, analisis sejarah masa berdasarkan dari sejarah masa gempa bumi di Aceh pada tahun 2004. Perisian komputer SAP2000 dipilih untuk menganalisis tindak balas gempa bumi kepada platform luar pesisir jaket keluli. Struktur keluli adalah direka bentuk mengikut piawaian Kod Euro 3.

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LIST OF SYMBOLS

$M\Delta$	Magnitude at a distance of Δ calculated from basic Richter formula
F	Wind force [N]
ρ	Mass density of air [$1.2\text{kg}/\text{m}^3$]
u	Wind speed [m/s]
C_s	Shape coefficient
A	Area of object [m^2]
F_D	Drag force per unit length of the member [N/m],
F_I	Inertial force per unit length [N/m],
C_D	Drag coefficient
w	Density of water [N/m^3]
V	Displaced volume of the cylinder per unit length ($=\pi D^2/4$) [m^3]
g	Gravitational acceleration [m/s^2]
U	Component of velocity vector due to wave [m/s],
$ U $	Absolute value of U [m/sec],
C_m	Inertia coefficient
$\frac{\delta U}{\delta t}$	Component of local acceleration vector of the water
E	Young Modulus
G	Shear modulus
A_v	Shear area , mm^2
f_y	Yield strength , N/mm^2
γ_{M0}	Partial factor
$\sigma_{all,s}$	Allowable Shear Stress
$V_{c,Rd}$	Design Shear resistance
A_c	Area mm^2
$M_{c,Rd}$	Moment resistance for cross section
W_{pl}	Plastic Modulus , mm^3

f_y	Yield strength , N/mm ²
$\sigma_{all,b}$	Allowable bending stress
S_x	Section Modulus ,mm ³
Ved	Maximum design shear force
σ_s	Shear Stress
Med	Maximum design bending moment
σ_b	Bending stress

LIST OF ABBREVIATIONS

MMD	Malaysia Meteorology Department
P	Primary wave
S	Secondary wave
CBF	Concentric braced frames
EBF	Eccentric braced frame
AASHTO	American Association of State and Highway Transportation Officials
IEM	Institute of Engineers Malaysia
API	American Petroleum Institute
EL	Environmental load
RS	Response spectrum
D	Dead load
L	Live load
TH	Time history

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

An earthquake is the consequence of a unexpected release of energy in the Earth's crust . This sudden energy release causes the seismic waves that make the ground shake that could creates seismic waves. Due to the consequence rock breaking , have result in energy waved which is seismic wave. It kind of energy that travels all the way through the earth. Seismic waves pass through either the length of the earth's surface or through the earth's interior .

Earthquakes are usually triggered when rock underground suddenly breaks along a fault. Fault plane is the underground surface along which the rock moves and breaks. By using seismograph it will determine the magnitude or size by measuring the amplitude of the seismic wave that occur and the distance of seismograph from the earthquake. The seismograph are consists of a seismometer (the detector) and a recording device that located at every station of possibility of an earthquake occur . The seismometer device will electronically amplifies the wave motion in earth.

Earthquakes caused too many damaging effects to the surrounding they act upon. This includes damage to man-made buildings structure and in worst cases the human death. The destruction of structures such as bridges ,dams and buildings are caused by the rumbling impacts which originated from the earthquake. Besides , earthquake can also trigger landslides that have bad effect on human life and animal life.

Earthquakes usually cause dramatic changes, including ground movements, dropping, dropping, and tilting of the surface cause different in the groundwater flow. Other than producing floods and damaging the buildings, earthquakes that occur under ocean can sometimes cause tsunamis or known as tidal waves. The tsunamis' conditions are high water which travel at a short period of time. They are surely destroying area in coastlines which effect entire populations and cities.

1.2 PROBLEM STATEMENT

On 26 December 2004 ,the coastal area off northern Sumatra , Indonesia had been struck by huge and massive earthquake which then triggered tsunamis around the neighboring countries such as India , Maldives ,Malaysia ,Thailand and Sri Lanka. Due to the massive earthquake that occur in Northern Sumatra, Indonesia magnitude 9.0 in Richter scale ,Malaysia was affected critically by this natural disaster. The earthquake in Indonesia had triggered tsunamis in coastal area Malaysia that caused to serious injuries , loss of human life, damage to man-made structure and etc.

Although Malaysia is near to the epicenter of the earthquake, Malaysia escaped from the kind of damage that struck another countries nearby the Sumatra. Since the western coast Sumatra is the epicenter of earthquake, Malaysia is largely protected by that island from the worst case of tsunami. Even though Malaysia is safely protected but still there are some part

in Malaysia that been affected such as Penang and Langkawi. It reported that number the number of life loss are 68 where in Penang (52) , Kedah (12), Perak (3) and Selangor (1) .Malaysia which located at the peripheral of the fire ring and near to Indonesia and Philippines that known had always occurs seismological activities in the past few years , shows that Malaysia could have a chance of being struck by at least one moderate earthquake.

In year 2012, Malaysian Meteorological Department had detected eight earthquakes in the eastern part Malaysia, Sabah and Sarawak which have magnitude between 2 and 4.5 scale Richter (Bernama, 2013).This shows that Malaysia cannot ignored the threat of an earthquake since there was record for existing earthquake even in small magnitude.Besides, in 1976 , the strongest earthquake ,magnitude 5.8 had been recorded in Lahad Datu, Sabah. “Malaysia is close to areas that have experienced strong earthquakes, including Sumatra and the Andaman Sea, while Sabah and Sarawak are located close to the earthquake zone of South Philippines and North Sulawesi. Therefore, the odds of an earthquake striking Peninsula Malaysia cannot be ruled out,” (Dr.Mohd Rosaidi Che Abas).

In record , there are about less than 10% man made structure in Malaysia that consider earthquake in the design. Although tendency Malaysia to be struck by massive earthquake is quite slim, but supposed the design cannot ignored the threat for moderate earthquake. Since the damage by the moderate earthquake could defect the existing structure by presence of crack. Lately, Prime Minister 5th Abdullah Ahmad Badawi had highlighted about the importance of consider impact of earthquake in Eurocode standard toward design structure in Malaysia. Thus , it really important to take account the earthquake impact in structure especially in design of offshore platform.

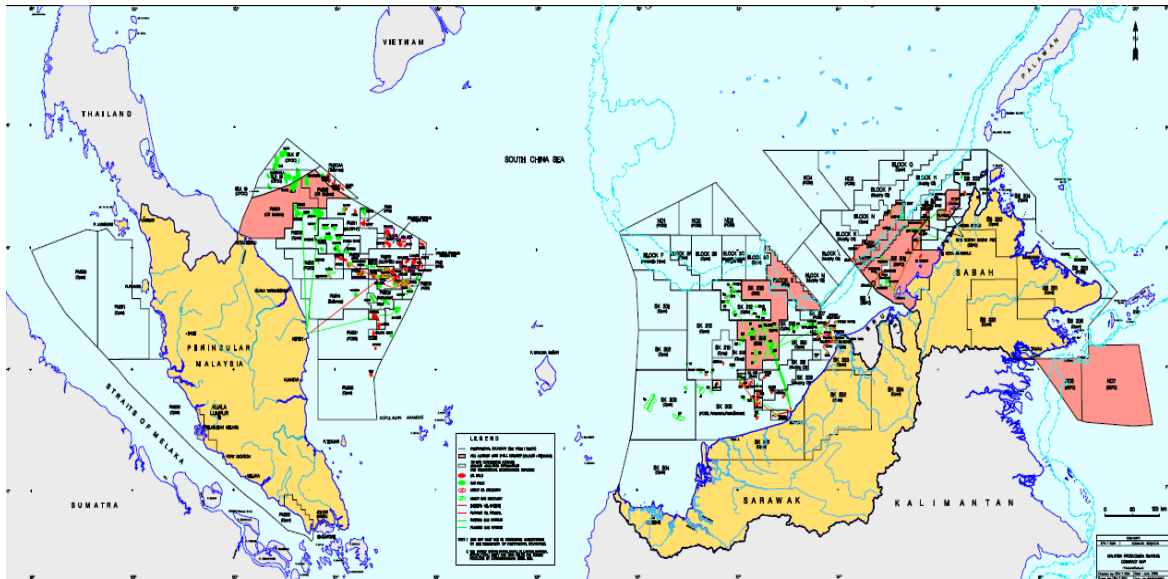


Figure 1.1 : Location of the offshore platform around Malaysia

Source:Minyakdangasmalaysia.blogspot (Online image).(2010) .Retrieved October 2, 2015
from <http://minyakdangasmalaysia.blogspot.com/2010/10/malaysias-oil-gas-maps.html>

1.3 RESEARCH OBJECTIVE

The main objective of this research are :

- i. To estimate the earthquake ground motion due to earthquake in Aceh Indonesia for assessment of offshore platform in Malaysia.
- ii. To determine the vulnerability of existing offshore platform in Malaysia when subjected to loading from earthquake.
- iii. To determine the response of the fixed steel jacket offshore platform under earthquake loading (shear, displacement ,and bending moment)

1.4 SCOPE OF STUDY

The scope of study are :

- i. The effect of earthquake to steel structure for jacket offshore platform.
- ii. The type of offshore platform used will be 3-legged fixed offshore platform.
- iii. The case study will be conducted at the Aceh earthquake region that affected the offshore platform in Malaysia.
- iv. The jacket offshore structure modeling and analysis software used is SAP 2000.
- v. The data analyzed for earthquake in Aceh is obtained from the Malaysia Meteorology Department (MMD).

1.5 RESEARCH SIGNIFICANCE

Throughout this research ,we could determine the behavior of the offshore structure under earthquake loading from Aceh earthquake. Thus , could identify the adequacy of existing offshore platform structure in Malaysia. By considering this earthquake resistance in our design structure, we could save more life, and prevented the worst damage in our steel structure at offshore platform

CHAPTER 2

LITERATURE REVIEW

2.1 EARTHQUAKE

2.1.1 Concept, Terminology and Source of Earthquake

The probability for a massive earthquake to struck comes in the first instance from the violent shaking of ground surface. This violent shaking could affect an area many hundreds of kilometers in radius. This is the primary damage which an earthquake engineer have to deal with. The seismic shaking causes direct effects on structures, due to the inertia forces set up by the ground accelerations, but important secondary sources of damage may also be arise (Booth & Key, 2008) .Usually large soil movement may happen due to liquefaction (the shear strength temporary loss in loose, sandy and saturated soils), consolidation, landslides or avalanches. Offshore earthquake also could triggered tsunamis (commonly referred as tidal wave) in coastal area.

Earthquake arise due to forces within the earth's crust tending to displace one mass of rock relative to another (Booth & Key, 2008). Failure in the rocks will occur when the forces occurs at point of weakness called fault plane. Besides, sudden movement which occur then will give rise to violent motions at earth's surface. The failure will starts from a point on fault plane which called the focus , and then propagates outwards until the forces are dissipated to level below the rock's failure strength. The fault plane may be in hundreds of kilometers long for large earthquake, and tens of kilometers deep. In large earthquake, usually fault plane will break up the surface, while for smaller earthquake, it will remains completely buried.

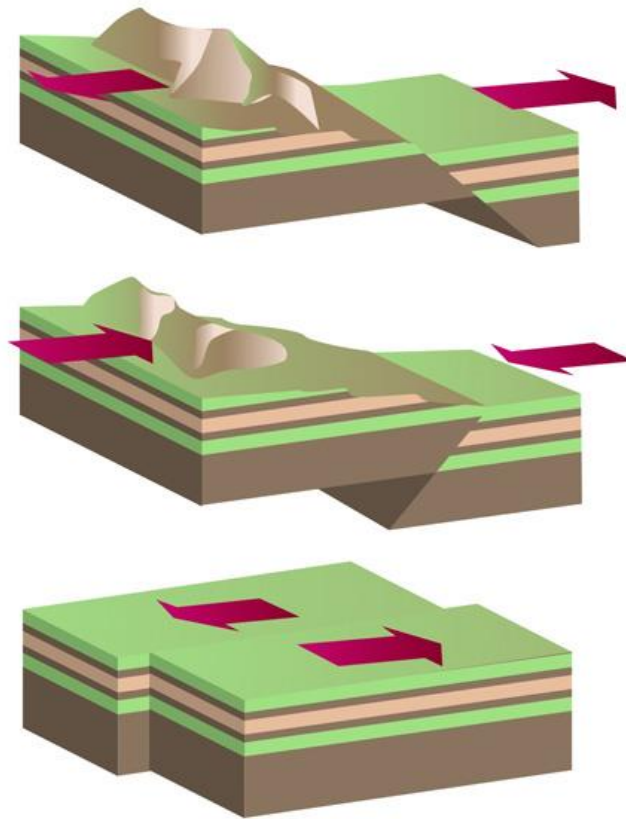


Figure 2.1 : Fault plane when earthquake occur

Source : sparkcharts.sparknotes [Online Image].(2011) .Retrieved September 23, 2014 from http://sparkcharts.sparknotes.com/gensci/geology_earthsci/section5.php

Earthquake do not usually occur as a single event as mostly assumed in seismic design, but as a series of shocks (A.Faisal, T.Majid, & G.hatzigeorgiou, 2013) .Massive earthquake have more and larger aftershocks ,foreshocks and the sequences could last for years and even longer. Earthquake aftershocks usually unpredictable and be higher magnitude which could possibly collapse building that damaged by main shock.

2.1.2 Magnitude and Intensity of Earthquake

For design in engineering, it is really critical to define the size of an earthquake .There are two measures of size of an earthquake which are in terms of magnitude and intensity .Earthquake magnitude is a fundamental property of the earthquake, related to its energy release on a logarithmic scale (Booth & Key, 2008).The energy released is from the source or focus of the earthquake. While, earthquake intensity describe the impact of the earthquake on the Earth's surface, by observing its effect on human kind and building structures.

The impact such as ground shaking on population, structures and the natural landscape, this impact will be greater if near to the focus earthquake. Unlike magnitude, intensity given earthquake rely on the location where it is measured. In general the larger the epicentral distance, the intensity will be lower. Hence a given magnitude of earthquake will give rise to more different intensities in the affected region.

The magnitude of an earthquake is related to energy amount of energy released by the geological rupture causing it and is therefore a measure of the absolute size of the earthquake without reference to the distance from the epicenter (K.Sen, 2009). The best known measure of earthquake magnitude was introduced by Charles Richter and known as Richter Scale which now referred as local magnitude (M_L)

To compare the magnitude of earthquake, use yardstick or scale created by C.F Richter. By using a formula of standard horizontal Wood-Anderson seismograph, the magnitude

$$M = \log_{10} A \quad (2.1)$$

Where A refer to the trace amplitude in micrometer for an epicentral distance of 100km. While for the distance from epicenter is other than 100km,

$$M = M\Delta - \frac{1.73 \log_{10} 100}{\Delta} \quad (2.2)$$

Where $M\Delta$ denoted magnitude at a distance of Δ calculated from basic Richter formula (Erdey, 2007).

2.2 SEISMIC WAVE

Earthquake will generate or trigger elastic wave when a block of material slides against another, hence the break between the two block is called 'fault'. Explosions that occur will generate elastic wave by an impulsive change of volume. If the equilibrium of a solid body like the earth is disturbed due to the fault motion resulting from an earthquake or explosion seismic (elastic) wave are transmitted through the body in all directions from the focus (K.Sen, 2009). The waves that radiated by an earthquake will lasts about tenths of seconds to several minutes. Rocks at this moment will behave like elastic solids at these frequencies. Due to the behavior of the elastic solids, it will allow the different types of wave to occur. Thus this will make ground motions quite complex to occur after an earthquake or explosion.

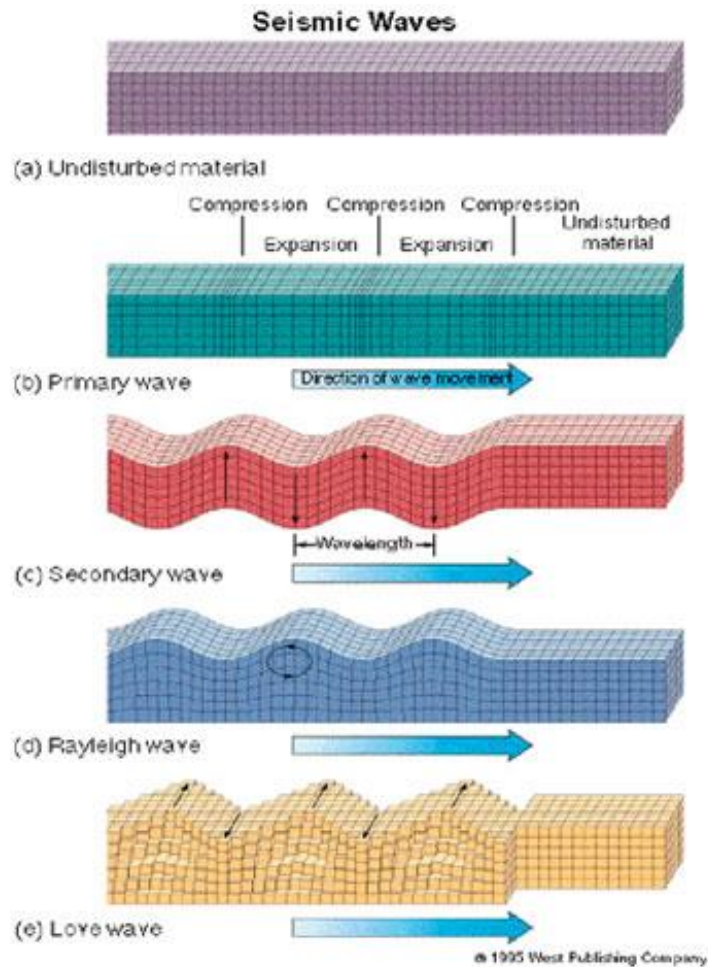


Figure 2.2 : Types of waves , P wave, S wave and Surface wave

Source : Electronic Field Trip [Online Image].Retrieved on October 10 , 2014 from

http://electronicfieldtrip.org/volcanoes/teachers/classroom_causes.html

2.2.1 Body Wave

There are two categories of seismic wave that produced during an earthquake which are primary wave (P) and secondary wave (S). P and S waves travel from the focus to the surface through the interior of the earth which refer as body wave. The velocities encountered

depend on the upon the elastic constant and densities of the materials and other properties of the surrounding medium (K.Sen, 2009) .

Primary wave (P) are the first wave to arrive which having the highest velocities. The second wave to arrive are the S (secundus) which have a tranverse,shear vibration in plane that perpendicular to the direction of propagation .The presence of two types of wave arise from the fact that there are two fundamental ways one can strain a solid body. Firstly by changing the volume without change the of shape. Secondly the change of shape without the change of volume.

The P or compression waves transmit the pressure changes through the Earth in a series of alternating compression and rarefactions. While for the S waves can only travel through solid ,therefore cannot travel through outer core of Earth's liquid. P wave can travel through the core,an Sv wave is one in which the ground motion (vibration) is vertical and an Sh wave refers to one where the ground motion is horizontal (K.Sen, 2009)

The reflections of waves back into the valleys and the conversion of body waves into surface waves at the boundaries of sedimentary basins, suggests that the parameters describing some horizontal dimensions of sedimentary basins should play a role in the description of the duration of strong earthquake ground motion (M.Trifunac & M.Todorovska, 2012)

2.2.2 Surface Wave

When the two types of body wave reach the surface of the Earth ,an interesting change occurs in the behavior of the waves. The combination of this two types of body wave in the